AN ABSTRACT OF THE THESIS OF

Mohamed Noureddine Ben Ali for the degree of *Master of Science*

in *Crop Science (Agronomy)* presented on *June 28, 1979*

Title: *YIELD AND QUALITY OF CEREALS FOR WINTER SILAGE PRODUCTION*

Abstract approved: Redacted for Privacy
William S. McGuire

A field study was conducted in 1978 and 1979 at two locations near Corvallis, Oregon, to determine the silage yield and quality of 13 fall-sown cereal varieties at two nitrogen fertilizer levels in the context of a corn-winter cereal, double cropping production system.

Data on the yield, crude protein (CP) content, acid and neutral detergent fiber (ADF and NDF) contents were collected on Adair, Casbon and FB 73130 barley (Hordeum vulgare L.) varieties, Amity, Cayuse and Grey winter oats (Avena Sativa L.), Abruzi and Kung rye (Secale cereale L.), S-72, Sel N-91 and VT 75-229 Triticale (Triticum X Secale) and Stephens and Yamhill wheat (Triticum Aestivum L.) varieties. The statistical analysis of the data gave the following results.

Dry matter yields ranged on the average from a high of 8327 kg/ha to a low of 4631 ka/ha. Abruzi rye generally yielded the most dry matter. It was followed by Sel N-91 and VT 75-229 Triticales, Kung rye, S-72 Triticale and the wheat varieties. The barley and oats varieties were generally the lowest producers.

Crude protein content was within the range of 6.5 to 10.1 percent of the dry matter. It was on the average highest for FB 73130 barley followed by Casbon barley, Stephens wheat, Adair barley, Yamhill wheat and the Triticale varieties.

Acid detergent fiber ranged from 30.8 to 46.4 percent of dry matter. The oats varieties had the lowest ADF values, followed by Stephens and Yamhill wheats, FB 73130 and Adair barleys and VT 75-229 Triticale.

The average neutral detergent fiber content for the 13 cereal varieties varied from a low of 50.3 to a high of 69.4 percent of D.M. The oats varieties were generally lowest followed by Stephens and Yamhill wheats, FB 73130 barley, VT 75-229 Triticale, Adair barley and Sel N-91 and S-72 Triticales.

Covariance analysis indicated that a strong linear relationship existed between the yield and the quality components of the cereal varieties. When CP, ADF and NDF contents were adjusted for the same yield, it was found that the nitrogen fertilizer effect was no longer significant for either ADF or NDF.

Yield and Quality of Cereals for Winter Silage Production

by

Mohamed Noureddine Ben Ali

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 28, 1979

Commencement June 1980

APPROVED:

Redacted for Privacy

Professor of Crop Science in charge of major

Redacted for Privacy

Head of Department of Crop Science

Redacted for Privacy

Dean of Graduate School

Date thesis is presented *June 28, 1979*

Typed by Erika Ben Ali for *Mohamed N. Ben Ali*

IN DEDICATION TO

My father, Hadj Belgacem Zribi and my mother, Aicha for their prayers and love.

My wife, Erika and my daughters, Nadia and Donia, who make life such a joy.

Acknowledgement

I wish to express my sincere gratitude to Dr. W. S. McGuire for his constant help, encouragement and guidance throughout the conduct of the experiment and during the course of my studies. I also wish to thank Dr. L. Vough for his help in getting the experiment and my course work under way and Dr. L. D. Calvin for his help and patient guidance in the analysis of the data. Special appreciation is also extended to the government of Tunisia, and the Agency of International Development for making my stay at Oregon State University possible. Finally, I wish to thank the Department of Crop Science for making land and facilities available for this study.

TABLE OF CONTENTS

LIST OF TABLES

YIELD AND QUALITY OF CEREALS FOR WINTER SILAGE PRODUCTION

I. INTRODUCTION

Pastures and machine-harvested forages are very important to dairy farm operations. They furnish the largest share of the nutrients for the dairy herd and are usually the cheapest source of feed. When included in a well orchestrated crop management system, forage crops can provide the dairymen with an economical, high quality, and year-round supply of feed for their animals.

In the Willamette Valley, as in many other parts of the United States and the world with similar climatic conditions, corn has been grown as a silage crop for a long period of time and has yet to be surpassed by any other forage crop in total digestible nutrients per unit area. However, in spite of the high quantities of silage produced by corn during the summer season, dairymen often find themselves in short supply of feed before the new corn crop is ready for harvest. Furthermore, the incessant rise in the cost of production inputs, makes the economical survival of dairy operations contingent upon the ability of their managers to increase their production efficiency. The drive toward lowering the cost of milk production and the search for a solution to the seasonal feed deficiency problem compel us to look for new farm management techniques, such as the double cropping system.

Double cropping has been used for centuries in some parts of the world but has unfortunately been neglected or ignored in other regions. Its potential in the tropics and temperate parts of the world could be developed tremendously with irrigation. Silage crops whose period of soil occupation is realtively shorter than grain crops because of the nature of the desired final product are ideally suited for the double cropping system.

In this system a winter cereal could be grown during the period of late October to early May and the remainder of the year devoted to the growing of the corn silage crop. Such a management technique would provide the dairyman with the extra feed he needs to fulfill his herd's requirements and also improve his management by increasing the return per unit area of his farm.

The object of this research is to investigate over a two-year period, at two locations and under the double cropping management system, the use of winter cereals to increase silage production on the dairy farm.

Small grain cereals are cool season annuals; winter cereals is a term used here to designate those cereal species or varieties that are sown in the fall. Because of their adaptability to a wide range of varying soils and climates, fall-sown cereals can easily be associated with corn in a double cropping management system that can be successfully adopted throughout the humid Mediterranean climates, the Pacific Northwest, and especially the Willamette Valley. Furthermore, winter cereals are adapted to almost any class of livestock. They are highly productive and when properly managed provide a highly palatable, very good quality feed.

This experiment concerns the evaluation of five cereal species: barley, oats, rye, Triticale and wheat, each represented by two or three varieties. They were studied in the context of a corn-winter cereal double cropping system with the following objectives:

A. Dry matter yields. Investigate thirteen varieties of the five cereal species mentioned above in order to determine and compare their dry matter yields.

B. Influence of nitrogen fertilizer on dry matter yields. Investigate the response of these thirteen cereal varieties to application of 133 kg/ha of nitrogen vs no nitrogen fertilizer application.

C. Quality of feed. Evaluate the relative quality of these varieties through determination of crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF).

D. Influence of nitrogen on quality. Investigate the effect of application of 133 kg/ha of nitrogen fertilizer on CP, ADF, and NDF concentrations.

II. LITERATURE REVIEW

1. Double Cropping

Double cropping or multiple cropping in general makes the best use of time and resources. Dalrymple (1971) pointed out that in practice multiple cropping may involve the cultivation of from two to as many as nine crops in sequence on the same land in a year. Double cropping is by far the most common, but triple and quadruple cropping are not unusual. Luh (1970) in a report on southeast Asian countries noted that multiples higher than quadruple cropping usually involve a pure rotation of vegetables and are found in very limited market garden areas.

Although it might seem the most advanced of agricultural techniques, multiple cropping is in some ways an anomaly: it has an ancient history but its practice is still largely confined to the less developed nations. Dalrymple (1971) noted that multiple cropping was carried out well before the time of Christ in some countries, and currently immense areas are so cropped in Asia. Yet, the area multiple cropped in the developed nations appears to be extremely small except for Japan where large areas are farmed under this system.

In the United States the most common forms of multiple cropping may be market gardens and greenhouse operations. A review of the literature offered very little in terms of information about double cropping of corn for silage with fall-sown small grains also for silage. Dalrymple (1971) pointed out that multiple cropping is carried out in several regions of the U.S. Although exact surfaces are unknown, agricultural census data have been used to derive an outside estimate which averaged around 5 million acres. Double cropping rotations involving a small grain such as winter wheat or barley followed by grain sorghum have been practiced in southern portions of the U.S. for 40 or 50 years. More recently, soybeans have joined sorghums as a second crop. In some of the southern states, double cropping involving a wheat-soybean combination is almost a necessity because wheat alone is not sufficiently profitable. In more northern states, buckwheat may be sown after early harvested small grains. The practice of double cropping has been facilitated by advances in the mechanizations of agriculture and particularly by the presence of the combine harvester.

In their publication, Camper, Genter and Loope (1972) told of their investigation of double cropping following winter barley harvest in eastern Virginia. In this experiment soybeans (Glycine max L.) for grain and sorghum (Sorghum vulgare L.) and maize (Zea mays L.) for both grain and silage were planted in late June and in July following winter barley (Hordeum vulgare L.) to evalute these crops in a double cropping system in eastern Virginia. Interpretation of the results showed that when the June plantings were harvested for grain, the net return from maize was significantly greater than from either sorghum or soybeans. Soybeans, however, appeared to be more dependable than maize or sorghum for grain if planted in July. Maize and sorghum silage yields were obtained the second year of the experiment. Net returns from both crops for silage were consistently greater at each date of planting than from any grain crop. All but one of the differences were significant.

Murdock and Wells (1978) conducted a double-cropping corn and small grain silage experiment at two locations in Kentucky and reported that as far as dry matter yields were concerned double cropped silage produced more dry matter than single-cropped silage. The average yield increase was 19 percent at the first location (Quicksand, Eastern Kentucky) and 31 percent at the second (Princeton, Western Kentucky) over a four-year period. The small grain contributed about one quarter of the total production at both locations. Furthermore, Murdock and Wells reported that even though small grains were cut in mid May (regardless of stage of maturity) in order not to reduce the production potential of corn, yields of the single-cropped corn silage were greater than that of double-cropped corn silage in all but two cases (Table 1). Although the average differences were small a fairly consistent trend existed. This was attributed to the removal of moisture from the soil profile by the small grains leaving the corn crop with less water to use for its own growth.

It was also found that small grain species and stage of maturity at harvest (mid-May) affected yields of the succeeding corn crop. Corn grown after barley which was in the soft dough stage at the time of harvest averaged 25 percent more yield than that grown after oats which was at heading at the same time of harvest.

In conclusion, Murdock and Wells suggested that a double cropping silage system should be managed to obtain maximum corn yield. They suggest that in order to achieve maximum double cropping yields corn should be planted early enough to ensure maximum yield potential. A small grain should be selected that would be close to the soft dough maturity stage by corn planting time.

Table 1. Yield of double-cropped and single-cropped silage at 35 percent dry matter at the medium fertility level (Murdock and Wells, 1976) (metric tons/hectare)

Year	Double-cropped Corn	Double-cropped Small grain	Double-cropped Total	Single-cropped Corn
---1st location = Quicksand---				
1970-71*	30.1	18.6	48.8	42.3
1971-72*	44.6	7.4	52.0	54.7
1972-73	41.2	17.3	58.4	39.6
1973-74	52.9	20.0	72.9	58.2
Average	42.1	15.9	58.0	48.8
---2nd location = Princeton---				
1970-71*	58.4	17.7	76.1	43.7
1971-72	42.3	14.5	56.8	45.8
1972-73	39.1	17.5	56.6	45.5
1973-74*	36.6	9.7	46.2	45.5
Average	44.2	14.8	58.9	45.1

*Double cropped and single cropped corn yields are significantly different from each other at the .05 level these years.

2. The Uses and Performance of Small Grain for Forage

Fall-sown cereals when grown for silage or hay constitute an extremely effective tool in helping the dairyman develop a year-round forage system. As with corn silage, small grain hay or silage is stored by the dairyman or by the livestock feeder in general to be used with other feeds or when these other feeds are unavailable. Also, grazing of small grains is practiced in farms all over the world; especially in those farm enterprises where efficient livestock production is being conducted.

The use of single-cropped, fall-sown cereals for quality hay or silage production has been studied and investigated quite extensively. Researchers have, among other things, looked into the yields of small grain forages and their behavior under different nitrogen fertilization levels, different soil conditions, etc. In one of the earliest published studies, Hendry (1925) stated that when barley, oats, wheat and rye were investigated for yield it was found that each of the four cereals possessed well-defined group characteristics which distinguished it from the others, irrespective of the varieties of which it is composed. As an example Hendry points out that barley under favorable conditions in the California great valley yields less hay per acre than the other three cereals. Yet, in drought years it becomes the most productive of the four. This same conclusion had been reached by Hansen (1891) who investigated barley, oats, and wheat yield in California's Amador County. Furthermore, Hendry stated that, as would be expected, the different varieties of each group react differently to climatic variations, and some are more injuriously affected by drought than others, but the general relationship of well defined group characteristics holds true for the group as a whole. In this study by Hendry, wheat under favorable circumstances was found to produce higher hay yields than the other cereals. It also produced more feed value per acre than barley, oat, or rye hay.

A study conducted in the Columbia basin by Jackman and Oveson (1955) led them to conclude that as far as yields are concerned, fall-sown wheat and fall-sown rye normally will out-yield spring grains for hay or silage. Barley is more likely to make a crop on thin, dry soils, or in years lacking subsoil moisture than other cereals. On the other hand in years with plenty of subsoil moisture, either wheat, oats or rye is likely to out-yield barley. Jackman and Oveson recommended that for deep, rich soils, north slopes, moist bottom lands farmers should use oats, which are well adapted to good conditions. For sandy lands low in organic matter, rye should be used. They also point out that nitrogen fertilizer usually increases hay yields more than grain yields.

In a comparative study involving fall and spring-sown cereals Fisher and Fowler (1975) reached the same conclusion as Jackman and Oveson with respect to yield potential of winter vs spring cereals. They noted that among the cultivars considered in their study which included wheat, Triticale, barley, oats and rye, a definite dry matter yield advantage was apparent for all winter crops except barley.

Tingle and Dawley (1974) working with several cultivars of wheat, Triticale, oats, and barley found that at the soft-dough stage Jubilee barley and a mixture of 40 percent Glen oats and 60 percent Jubilee barley produced significantly higher DM yields than Warrior and Piroline barley and Pitic 62 spring wheat. They report that Raymond and Heard (1968) also found that spring barley and oats produced more dry matter than spring wheat at the soft-dough stage. Tingle and Dawley also found that Rosner Triticale, and Apam and Brigitta barley were lower in yield than Glen oats and the Glen/Jubilee mixture.

In a study by Brown and Almodares (1976), quality and quantity of Triticale for forage were compared with other small grain forages during two seasons. In 1972, the forage production of Fasgro 514 and Fasgro 385 Triticale was similar to Jefferson oats and Halley wheat but less than Athens Abruzi and Winter Grazer 70 rye. Fasgro 131 and Fasgro 385 Triticale produced as much forage as Jefferson oats, Winter Grazer 70 rye and Funks rye-wheat mixtures in the 1974 crop season. These two Triticale cultivars were more productive than Hollez wheat but less productive than Athens Abruzi rye during the 1973-74 season. The winter hardy Triticales, Fasgro 131 and Fasgro 385 produced the bulk of their forage in late winter and early spring. Triticale cultivars with upright growth habit exhibited more winter killing during the 1971-72 season than those having a prostrate habit of growth. In 1978 Bishnoi et al obtained results similar to those of Brow and Almodares. Investigating the yields and quality of Triticale, wheat, barley, oats, and rye, they found that at 2 harvesting stages (> 50 percent bloom and soft-dough) Triticale produced more forage and silage than the other crop cultivars during the two growing seasons of the experiment (1974-75 and 1975-76). The percent of dry matter, however, was significantly higher in rye at both harvest stages each year than that found in the other crops. They concluded that results of their comparative study on silage and dry matter yield performance of Triticale cultivars GTA 131 and GTA 298 with wheat, rye, barley and oats showed that Triticale can be used for ensiling and the dough stage harvest produces acceptable yields and better quality silage.

3. Small Grain Forage Quality

Before the end of the nineteenth century, forage quality or nutritive value of forages was not scientifically quantified. Organoleptic senses were used to distinguish between hays or silages of good or poor feeding value. However, with the development of chemistry as a branch of agricultural science it became natural to look into the chemical composition of forages as a means of delineating forage quality. In the 1850's the Weende system for the proximate analysis of forages was introduced. Basically this system divided the forage dry matter (DM) into several fractions among which are crude protein (CP = N x 6.25), ether extract, ash, and a carbohydrate fraction partitioned into crude fiber (CF) and nitrogen-free extract (NFE). The partitioning of this carbohydrate fraction by the proximate analysis into crude fiber and nitrogen-free extract was supposed to represent a separation of the less digestible cellulosic carbohydrate from the readily digestible starch and sugars. Unfortunately, it did not and thus it was discovered that in approximately 25 percent of the feeds listed by Morrison (1956-58) the NFE was less digestible than the fiber. The reason for this discrepancy was the failure of the crude fiber chemical method (successive boiling with SO_4H_2 and NaOH) to recover all the fiber of a forage so that a large portion of this undigestible fiber such as ligno-cellulose was extracted in the NFE.

Since 1967 and especially in 1970-71 Van Soest and Georging (1970) combined their research efforts with results obtained by Crampton and Maynard (1938) to develop an alternative to the proximate analysis.

This new system was called by Van Soest (1976) a general system of analysis. With the use of detergents this method accomplished a division of the forage or plant dry matter into two components:

-- A cell content fraction (CC) almost completely digested (98%), soluble in neutral detergent and mainly constituted of water solubles, lipids and protein.

-- A cell wall fraction (CWC) insoluble in neutral detergent and commonly referred to as neutral detergent fiber (NDF). This fraction contains two components, one soluble and one insoluble in acid detergent. The first is usually referred to as acid-detergent soluble and represents hemicellulose plus insoluble protein. The second is called acid detergent fiber (ADF) and represents 98 percent of the indigestible forage fraction, namely lignocellulose.

This new chemical method of forage evaluation became very widely used, so much so in fact that the forage analysis sub-committee of the American Forage and Grassland Council (AFGS) surveyed US scientists working with forage quality and animal nutrition in order to obtain a concensus of opinion relative to more precise techniques for evaluation of forage quality. The majority of the respondents indicated that the analysis for acid detergent fiber (ADF) and neutral detergent fiber (NDF) were the chemical assays of choice for estimating in vivo digestible dry matter (DDM) and dry matter intake (DMI), respectively. These two estimates (DDM & DMI) are the most important factors in determining the nutritive value of a feed.

Small grain forages differ among themselves in their content of feed nutrients even when harvested at the same stage of maturity. Many factors including soil fertility, amount of rainfall and temperature have a significant influence on the nutritive value and chemical composition of forages.

In a study conducted by Woll (1925) it was found that based upon chemical analysis barley appeared to be the most valuable hay since it was high in protein and starch and low in fiber. However, when it was included in feeding tests with other small grains it ranked second after wheat hay in nutritive value. This same test also showed that the nutritive effect of oat hay fed as sole feed, was considerably lower than that of wheat, barley or rye hay.

Contrary to Woll's results Thatcher (1934) found that oats had the highest crude protein content and made the best hay. However when wheat hay was cut in the early milk stage and cured well it was found to be very palatable and equaled oats in crude protein when the latter was cut at the soft dough stage. Thatcher stated that if barley is cut for hay at the milk stage of the kernal, when feeding value is high, the beards are tough and cause more trouble to livestock than if the crop is cut at a more mature stage, at which time the beards are brittle. Hooded barley, Thatcher noted, made inferior hay and silage because of low palatability and nutritive value. Of all the small grain hay crops, Thatcher ranks rye as the least desirable because of its very low palatability and high fiber content.

Thatcher also discovered that protein content of wheat or rye hay may be increased under certain circumstances by top-dressing the stand in the spring with readily available nitrogen fertilizer. The effect, he contends, is more pronounced on soils that are deficient in available nitrogen and during seasons when low temperatures and excessive soil moisture retard nitrification in the soil.

Davidson and Leclerc (1918) applied nitrate of soda at the rate of 320 pounds per acre to wheat at three stages, early in the spring when the plants were two inches tall, at heading time, and at the milk stage of the kernel. It was also applied as split applications between two or three of these stages. A study of their results led them to believe that the plants that received the application of nitrate of soda at the second or heading stage showed an increase in protein content proportional to the amount applied.

In 1955 Jackman and Oveson studied small grain hay and silage quality and found more differences in quality among varieties of the same grain than there is among the grain species themselves. This is perhaps the reason why Woll and Thatcher differed in their results and pointed out two different cereal species as being the best in quality when harvested for hay. In fact due to the great within-species variation a high quality barley variety could conceivably make a better forage than the average of several oat or wheat varieties. Jackman and Oveson conclude that on the average oats were higher in percentage of leaves, followed by barley, wheat and rye; and that in general the grain varieties that are the leafiest and tended to lodge in good years make the best animal feed. Palatability studies conducted by these scientists suggested that livestock of all kinds seem to know that protein is good for them. Other things being equal they showed strong preference for the earliest cut hays and if all the small grain hays are cut at the same maturity, livestock usually will choose hay of oats, wheat and rye in that order.

In more recent studies on the quality of wheat, wheat-rye mixture, oats, rye and Triticale forages Brown and Almodares (1976) reported that the rye-wheat mixture had the lowest percent protein of all cereals probably due to the early maturing rye selection used in the mixture. The crude protein content of the Triticale forage at comparable stages of growth was similar to rye, wheat and oats. The Triticale cultivars also had lower cell wall content (NDF) than rye or rye-wheat mixtures late in the season. However, their cell wall content was similar to Holley wheat and oats for all cuttings except the last one for oats in the last year of the experiment. Brown and Almodares concluded that the quality of Triticale forage was comparable to Jefferson oats and Holley wheat.

Burgess et al. (1973) compared corn silage to that of wheat, forage oats, barley and a grain mixture. They noted that crude protein (CP) levels showed considerable variation in the cereals compared for the 2 years of the experiment. CP values ranged from 8.6 to 20.7 percent, but in general the cereal silages exhibited only a very slight advantage over corn silage in crude protein content. Forage oats, because of a large row spacing (35 cm), had the highest ADF followed by barley and wheat.

Tingle and Dawley (1974) found that average CP values for barley, wheat, oats and Triticale were 10.8, 10.5, 9.4, and 9.7 percent, respectively. Lawes and Jones (1971) also found that whole-plant oat cultivars were slighly lower in protein than wheat and barley, but their average values only ranged from 5-7 percent CP when harvested 3-4 weeks after ear emergence. Tingle and Dawley note that although Triticale grain is reputed to have high protein levels, whole-plant Rosner Triticale harvested at a silage stage was comparatively low in CP in their study.

III. MEANS AND METHODS

The experiment was conducted during two growing seasons (1978 and 1979) and at two locations: the Hyslop Agronomy Farm and the O.S.U. Dairy Center. Both of these locations are near Corvallis, Oregon. Different sites were used at both locations for the second year test.

The climate of Corvallis (Calhoun, 1961), which is fairly representative of much of the Willamette Valley, may be described as a generally mild sub-coastal type with moist open winter, a dry harvest period in late summer and a fairly long growing season. The average rainfall for Corvallis (1901-1960) is 980 mm and the average frost-free period (217 days) extends from April 2 to November 5.

Soil types at the two test sites are different:

Hyslop Farm -- The Hyslop Farm soil can be described as a moderately well drained Woodburn silt loam (OR Soils - 1, 3-7-73) practically flat and with no weed problems. Sample analysis prior to seeding showed it to be moderately acid (pH = 5.8 in 1978 and pH = 5.3 in 1979) and containing on the average more than adequate amounts of phosphorus (≃ 95 ppm) and potassium (≃ 365 ppm).

Dairy Center -- The dairy center location had a somewhat poorly drained, Amity silt loam soil (OR Soils - 1, 2/1973). The flat areas are often temporally flooded during the raining season. Sample analysis showed it to be moderately acid (pH = 5.9 in 1978 and pH = 5.2 in 1979) and less fertile than the Hyslop soil. Phosphorus was an average value of 71.5 ppm for the 2 years and potassium was an average level of 144.5 ppm for the same period.

Because of the presence of higher amounts of phosphorus and potassium in the soil at the time of analysis no extra P and K fertilizer was applied to the experimental plots.

1. Materials

The thirteen fall-sown small grain varieties included in the experiment came from the following five cereal species:

Barley (Hordeum vulgare L.)--It is often referred to as the poor man's cereal. It is a hardy and drought-resistant plant. Barley grain is used to feed humans as well as animals. It is also grown for forage. The plant is well adapted to the semi-arid regions of the world where it matures early and offers a good chance of survival to both humans and animals. In this study barley is represented by three varieties: Casbon, Adair, and Fb 73130 barley.

Oats (Avena sativa L.)--This grain is consumed by humans only after processing. It has been grown for forage for a long time and it has always made excellent feed, especially for horses. Oats in general is not as hardy as barley or rye. Some oats varieties are susceptible to damage by winter cold. The Amity, Cayuse and Grey Winter oats varieties are part of this investigation.

Rye (Secale cereale L.)--This is the most winter hardy of all fall-sown cereals. It can easily withstand long freezing periods in the winter. Although early maturing and a good biomass producer, rye offers a low quality, stemmy forage. Abruzi and Kung are the varieties of concern to this experiment.

Triticale--This is a man-made species which resulted from the cross of wheat (Triticum) with rye (Secale). In spite of their problems with sterility and shriveled seed, Triticale varieties have shown great promise in producing both grains and forages. Three new lines are included this experiment. They are cultivars Sel N-91, VT75-229 and S.72 Triticale.

Wheat (Triticum aestivum L.)--wheat has received a good amount of attention in the past 20 years, and, as a result, its capacity for grain production has tremendously increased. Very little has been done to improve whole plant yield of wheat for use by livestock. Its potential is great, particularly when one considers high yielding varieties like Yamhill and Stevens.

The yield of these thirteen varieties was investigated at 2 nitrogen levels: zero and 133 kg of N/ha. The zero level was included in order to learn whether or not N fertilizer residues of the preceeding double cropped corn silage could carry the cereal crop to an acceptable yield level. Nitrogen fertilizer was provided in 3 split applications. It was broadcast with a 1.2 meter Gandy spreader. Table 2 shows the nitrogen source, rate and time for each application during the 2 growing seasons.

The seeding rates used were about 15 percent higher than those recommended for cereal grain production in the Willamette Valley. (Table 3 shows the varieties, seeding rates and dates for the two growing seasons (1978-79).

Table 2. Source of N, rate and time of applications during 1978-1979.

Source of N	Rate of Application kg of N/ha	Time of Application
Ammonium sulfate	23	2 wks after planting
Ammonium nitrate	55	2/28/78; 3/8/79
Ammonium nitrate	55	4/1/78; 3/30/79

Table 3. Variety, seeding dates* and rates used in 1978 and 1979 at Hyslop and Dairy Center experimental sites.

Varieties	Seeding rate kg/ha
Adair barley	133
Casbon barley	133
FB 73130 barley	133
Amity oats	144.5
Cayuse oats	144.5
Grey winter oats	144.5
Abruzi (N.C. selection) rye	111.2
Kung rye	111.2
Sel N-91 Triticale	239
VT 75-229 Triticale	166.8
S-72 Triticale	166.8
Stephens wheat	166.8
Yamhill wheat	166.8

* Hyslop seeding dates were: November 8, 1977 (for 1978)
October 11, 1978 (for 1979)

Dairy Center seeding dates: October 21, 1977 (for 1978)
October 12, 1978 (for 1979)

2. Methods

Experimental Design

The experiment was set up as a factorial arrangement of treatments in a split plot design, with N as whole plot and varieties as subplots. All treatments were replicated four (4) times. At the dairy center location one replication in 1978 and two replications in 1979 were lost because of flooding. The Hyslop farm data was averaged every year so that data for the four replications was combined to make only two. This procedure balanced the experiment and permitted the analysis of the data through the computer.

A. Field Procedure

In the fall of 1977 and 1978 the thirteen cereal varieties were planted in 5 x 18 foot plots with an Oiyer (15 cm between rows) self propelled drill. Approximately 2 weeks after planting the first application of nitrogen fertilizer in the form of ammonium sulfate 21 percent was applied at a rate of 22 kg N/ha. It was broadcast over the plots with a 1.2 meter wide Gandy spreader.

On February 28 and April 1 of 1978 (March 8 and March 30 for 1979) the 2 remaining applications of fertilizer were applied in the form of ammonium nitrate 33 percent at a rate of 55 kg of N/ha each. Early in the spring .45 meters was clipped off the end of each plot so that plot length was reduced to 4.5 meters. Harvesting of all plots took place during the first week of May regardless of the stage of maturity of the small grain varieties. This was done in order to simulate the conditions that would have been imposed by the double cropping of the cereals with irrigated corn. Harvesting was with a Carter harvester which is a 1.2 meter wide silage chopper. The chopper was run in the middle through the length of the clipped plots 4.5 meters long), thereby harvesting a 1.2 meter wide swath leaving a 30 centimeter band of plant material on either side and hence eliminating the border effect. The chopped plant material was collected in plastic bags and weighed immediately after harvest. Then the total amount of material harvested for each plot was deposited on a trailer platform, mixed thoroughly and 2 small (0.800 kg) samples were taken in 1978 (only one in 1979). The samples were secured in burlap bags, weighed and dried for a period of 5 days at a temperature of 48.9°C (for chemical analysis sample) and 65.5°C (for dry matter determination samples). The relatively low drying temperature of 48.9°C was used on the chemical analysis sample in order to avoid disturbing the chemical nature of the nutritive components of the forage. After drying the samples, dry matter weight was determined and dry matter yield (in kg/ha) for each variety was calculated.

B. Analytical Methods

The dried forage (1978 Hyslop crop) was ground in an Abbe Mill with a 20 mesh screen. Samples were taken from this ground material and the following analyses were run at the OSU agricultural chemistry laboratories:

Crude protein -- Values for CP were obtained by determining the total Kjeldhal nitrogen (Kjeldah method) and multiplying it by the conversion factor 6.25.

Acid detergent fiber (ADF) and neutral detergent fiber (NDF) or percent cell wall -- These were determined by the Goering and Van Soest method (1970).

IV. RESULTS AND DISCUSSION

1. Dry Matter Yields (DM)

Because of the loss of the Cayuse oats variety from the experiment due to the cold temperatures of January, 1979, it will not be part of the discussion on yield.

A. Effect of Varieties on DM Yields

The preliminary analysis of variance (Appendix Table 1) indicated that on the average both nitrogen and varieties had a significant effect on yield; it also indicates that the year x variety, location x variety interactions are significant.

Examination of the variety x year table of yield means (Table 4) showed that in 1978 Sel N-91 Triticale, Abruzi rye, VT 75-229 Triticale and Yamhill and Stephens wheats had the highest yield respectively. Although their yields were not significantly different from one another, those varieties significantly outyielded the oats, Kung rye and the FB 73130 and Casbon barleys. S-72 Triticale and Adair barley yielded significantly less than Sel N-91 Triticale and significantly more than the FB 73130 and Casbon barleys. In 1979, Abruzi rye, VT 75 Triticale and Sel N-91 Triticale (also the top three in 1978) significantly outyielded the wheats, the barleys and the oats. Kung rye and S-72 Triticale yielded significantly less than Abruzi rye and significantly more than the Casbon and FB 73130 barley and the oats. During both years the oats and the barleys were at the boot or preboot stage of maturity explaining why during both years they produced substantially low yield. This alone suggests that they might not fit in the rigid calendar of the double cropping system, since neither the barleys nor the oats reached their near optimum stage of maturity at the time of harvest.

The location x variety table of yield means (Table 5) shows that at the Hyslop location Abruzi rye produced a significantly higher dry matter yield than any of the other cereal varieties. VT 75-229, Sel N-91 and S-72 Triticales were respectively second, third and fourth, although comparatively similar to one another. They yielded significantly more than the oats and the FB 73130 and Casbon barleys which had the lowest yields. Kung rye, Adair barley and the wheat produced significantly less than Abruzi rye and the VT 75-229 Triticale and significantly less than the Casbon and FB 73130 barleys. At the dairy center location, Sel N-91, VT 75-229 Triticales, Abruzi rye and Yamhill wheat had the highest yields. They were significantly superior to those of the oats and FB 73130 and Casbon barley which were the lowest. Stephens wheat, S-72 Triticale, Kung rye and Adair barley produced significantly less than Sel N-91 Triticale.

During both experimental years and at the Hyslop and dairy center locations the varieties Abruzi rye, Sel N-91 Triticale and VT 75-229 Triticale were fully headed at the time of harvest. All three were comparatively at the most advanced stage of maturity. This and the fact that they all are relatively high growing cereal species are the reasons why these three varieties have consistently produced the highest yields. On the other hand the barley and oats varieties were all at the least developed stage of maturity and thus did not reach at the time of harvest their potential level of biomass production. It appears then that since harvest time

Table 4. Mean dry matter yields kg/ha of 12 fall-sown cereal varieties during the 1978 and 1979 growing seasons

Variety	1978(1)	Variety	1979(1)	Differences (1979-1978)(2)	Average Yield(3)
Sel N-91 Triticale	8062	Abruzi rye (NC Sel)	9128	+1602	8327
Abruzi rye (NC Sel)	7526	VT 75-229 Triticale	8106	+ 759	7727
VT 75-229 Triticale	7347	Sel N-91 Triticale	7834	- 228	7948
Yamhill wheat	6772	Kung rye	7117	-1264	6485
Stephens wheat	6711	S-72 Triticale	6932	- 294	6785
S-72 Triticale	6638	Yamhill wheat	6083	- 689	6427
Adair barley	6534	Stephens wheat	5944	- 767	6328
Amity oats	6019	Adair barley	5775	- 759	6154
Kung rye	5853	Casbon barley	4976	+ 690	4631
Grey winter oats	5444	FB 73130 barley	4731	- 119	4790
FB 73130 barley	4850	Grey winter oats	4088	-1356	4766
Casbon barley	4286	Amity oats	4008	-2011	5014

(1) $L.S.D._{.01} = 1358$

Varieties joined by same line are not significantly different

(2) $L.S.D._{.05} = 3553$

(3) $L.S.D._{.01} = 960$

Table 5. Mean dry matter yields in kg/ha of 12 fall-sown cereal varieties at the Hyslop Agronomy Lab (location 1) and the Dairy Center (location 2)

Variety	Location 1 (1)	Variety	Location 2 (1)	Difference (Loc. 2-Loc. 1) (2)
Abruzi rye	9915	Sel N-91 Triticale	7523	-2392
VT 75-229 Triticale	8465	VT 75-229 Triticale	6988	-1477
Sel N-91 Triticale	8373	Abruzi rye (NC Sel)	6739	-1634
S-72 Triticale	7594	Yamhill wheat	6338	-1256
Kung rye	7071	Stephens wheat	6152	- 919
Adair barley	7013	S-72 Triticale	5976	-1037
Yamhill wheat	6517	Kung rye	5899	- 618
Stephens wheat	6504	Adair barley	5296	-1208
Amity oats	5860	FB 73130 barley	4472	-1388
Grey winter oats	5334	Grey winter oats	4198	-1136
Casbon barley	5145	Amity oats	4167	- 978
FB 73130 barley	5108	Casbon barley	4117	- 991

(1) $L.S.D._{.01} = 1358$

Variety means joined by same line are not significantly different.

(2) $L.S.D._{.05} = 3553$

cannot be delayed without a significant reduction in the yield of the subsequent corn silage crop (Camper, et al. 1972), the barley and oats varieties should not be seriously considered in a double cropping system.

B. Effect of nitrogen on D.M. yields

The analysis of variance (Appendix Table 1) showed that the overall nitrogen effect was highly significant. It also showed that a year x nitrogen interaction existed and was significant at the 10 percent level of confidence. The nitrogen x year table of yield means (Table 6) indicates that during the 1978 growing season the application of 120 pounds of N/acre increased yield by a highly significant 170 percent. In 1979 the increase, although smaller than that of 1978 (only 60 percent), was still statistically significant. Table 6 also shows that at the Hyslop agronomy farm where the soil is relatively rich and well drained the application of 120 pounds of N/acre increased yield by a significant 67 percent; whereas at the dairy center location, where the soil is less fertile and less well drained, the nitrogen application increased yield by a highly significant 181 percent.

Table 6. The effect of nitrogen on the mean yield in kg/ha of 12 cereal varieties during 1978 and 1979 and at the Hyslop and Dairy Center locations

Nitrogen	Years				Locations		
	1978	1979	Dif	Average	Loc. 1	Loc. 2	Dif
Zero	3416	4720	1304	4068	5172	2963	-2209
133 kgs/ hectare	9257	7734	-1523	8496	8644	8347	- 297
Difference	5841**	3014*		4428**	3472*	5384**	

*L.S.D.$_{.05}$ = 2095: L.S.D. for comparing different nitrogen means within the same year and the same location

**L.S.D.$_{.01}$ = 3475

*L.S.D.$_{.05}$ = 2964: L.S.D. for comparing different year and location means within the same nitrogen level

**L.S.D.$_{.01}$ = 4915

2. Crude Protein

A. Crude Protein Content

The crude protein (CP) content of the thirteen cereal varieties of this experiment ranged from a mean low of 5.1 percent of the dry matter for the non-fertilized Abruzi rye to a mean high of 11.03 percent of DM for the fertilized Casbon barley. The analyses of variance for CP content and yield (Appendix Table 2) showed that both nitrogen and varieties affected CP content and yield significantly. However, the nitrogen x variety interaction for CP was also shown to be highly significant.

The variety x nitrogen data (Table 7) show that when no nitrogen is applied, FB 73130 barley had a significantly higher CP content than all of the other varieties. Casbon barley and Kung rye ranked respectively second and third and were not significantly different from the wheats, grey winter oats or Adair barley. No other significant differences could be seen among the varieties. At the 133 kgs of N/ha treatment, the barley, wheat and Triticale varieties had a similar but significantly higher CP content than that of the oats and Abruzi rye.

Table 7. Mean crude protein content in percent of DM of 13 cereal varieties at two nitrogen fertilizer levels

Variety	Zero nitrogen	Variety	133 kg/N/ha	Average
Fb 73130 barley	9.550	Casbon barley	11.030	9.5
Casbon barley	7.97	Stephens wheat	11.000	8.7
Kung rye	6.68	Adair barley	10.700	8.6
Grey Winter oats	6.600	S-72 Triticale	10.680	8.3
Yamhill wheat	6.58	Fb 73130 barley	10.650	10.1
Adair barley	6.48	Yamhill wheat	10.230	8.4
Stephens wheat	6.43	Sel N-91 Triticale	10.230	8.1
VT 75-229 Triticale	5.98	VT 75-229 Triticale	10.000	7.9
Amity oats	5.93	Kung rye	9.530	8.1
Sel-N-91 Triticale	5.900	Amity oats	9.180	7.6
S 72 Triticale	5.83	Grey Winter oats	8.980	7.8
Cayuse oats	5.600	Cayuse oats	8.180	6.9
Abruzi rye	5.100	Abruzi rye (NC selection)	7.960	6.5

$L.S.D._{0.01} = 1.57$

Varieties joined by the same line are not sigificantly different.

B. Effect of Nitrogen on Crude Protein

Table 8 shows that nitrogen applications significantly increased the CP content of all varieties except that of FB 73130 barley whose CP content increased by only 11.5 percent. The highest increase in CP content came about with S.72 Triticale with 83.2 percent, followed by Sel N-91 Triticale with 73.4 percent, Stephens wheat with 71.2 percent and VT 75-229 Triticale with 67.4 percent.

C. Adjusted Crude Protein Content

Further analysis (Appendix Table 2) revealed there was a highly significant linear relationship between crude protein content and the yield of the cereal varieties. The covariance analysis of CP on yield showed that even though much of the variation in CP content was accounted for by variation in yield, a significant part of this CP variation came about as a result of the application of nitrogen[1/]. It showed however that the nitrogen x variety interaction for the adjusted CP was highly significant.

Examination of this two way interaction table of means (Table 9) shows that at the no nitrogen treatment FB 73130 barley had the highest CP content. Casbon barley ranked second and had a significantly higher CP content than Adair barley, Stephens wheat, Amity and Cayuse oats, the

---

[1/]Error b was used to test nitrogen (main) effects. This is a split-plot design where error a has only 3 degrees of freedom and is actually less than error b; where as by theory it should not be. So it is assumed that error b is larger than error a only by chance and thus error b is a better estimate of the true value of error a. (Anderson & McLean)

Table 8. Differences due to the effect of nitrogen on the mean CP content in percent of DM of 13 cereal varieties

Variety	----------Nitrogen----------		Difference
	No nitrogen	133 kg/N/ha	
Yamhill wheat	6.58	10.23	3.65**
Stephens wheat	6.43	11.000	4.58**
Cayuse oats	5.600	8.180	2.58**
Grey Winter oats	6.600	8.980	2.38**
Amity oats	5.93	9.180	3.25**
Casbon barley	7.98	11.030	3.05**
Adair barley	6.48	10.700	4.23**
FB 73130 barley	9.55	10.65	1.10 NS
Kung rye	6.68	9.530	2.85**
Abruzi	5.100	7.95	2.85**
Sel N-91 Triticale	5.900	10.230	4.33**
VT 75-229 Triticale	5.98	10.000	4.03**
S-72 Triticale	5.83	10.68	4.85**

$L.S.D._{.01} = 2.05$

* significant at the 5 percent level

**significant at the 1 percent level

Triticales and Abruzi rye which ranked last. At the 133 kgs of N/ha treatment the barleys, Stephens wheat and S-72 Triticale had a significantly higher CP content than Cayuse oats and Abruzi rye which had the lower CP concentration. Yamhill wheat, Kung rye and Sel N-91 and VT 75-229, Triticales were not significantly lower in CP than Stephens wheat, S-72 Triticale or Adair barley.

D. Effect of Nitrogen on the Adjusted Crude Protein

As shown in Table 10, nitrogen application had a direct and significant effect in increasing the adjusted crude protein content of S-72 Triticale (45.3 percent), Sel N-91 Triticale (32 percent), Adair barley (32 percent), Stephens wheat (30.8 percent), VT 75-229 Triticale (26.4 percent) and Casbon barley (161 percent).

Table 9. Mean adjusted (for yield) CP content in percent of DM of 13 cereal varieties at two nitrogen treatments

Variety	Zero Nitrogen	Variety	133 kgs/N/ha
FB 73-130 barley	11.29	Casbon barley	10.95
Casbon barley	9.43	FB 73130 barley	10.37
Grey Winter oats	9.12	Stephens wheat	9.99
Yamhill wheat	9.10	S-72 triticale	9.66
Kung rye	7.76	Adair barley	9.65
Stephens wheat	7.64	Yamhill wheat	9.21
Adair barley	7.31	Kung rye	8.90
Amity oats	6.81	Sel N-91 triticale	8.80
VT 75-229 triticale	6.70	VT 75-229 triticale	8.47
Sel N-91 triticale	6.65	Grey Winter oats	8.07
S-72 triticale	6.65	Amity oats	8.07
Cayuse oats	6.16	Cayuse oats	6.73
Abruzi (NC Sel) rye	5.32	Abruzi (NC Sel) rye	6.07

$L.S.D._{.01} = 1.72$

Varieties joined by the same line are not significantly different.

Table 10. Difference due to the effect of nitrogen on the adjusted mean CP content in percent of DM of 13 cereal varieties

Variety	-------Nitrogen--------		Difference
	Zero	133 kgs/N/ha	
Yamhill wheat	8.10	9.21	1.11
Stephens wheat	7.64	9.99	2.35**
Cayuse oats	6.16	6.73	.57
Grey Winter oats	8.12	8.07	- .05
Amity oats	6.81	8.07	1.26
Casbon barley	9.43	10.95	1.52*
Adair barley	7.31	9.65	2.34**
FB 73130 barley	11.29	10.37	-0.92
Kung rye	7.76	8.90	1.14
Abruzi (NC Sel) rye	5.32	6.07	0.75
Sel N-91 triticale	6.65	8.8	2.15**
VT 75-229 triticale	6.70	8.47	1.77**
S-72 triticale	6.65	9.66	3.01**

$L.S.D._{.01} = 1.72$

* Significant at the 5% level

**Significant at the 1% level

3. Acid Detergent Fiber

A. Acid Detergent Fiber (ADF) Content

Acid detergent fiber content ranged from 23.65 percent of dry matter (DM) for the non-fertilized Grey Winter oats to a high of 46.78 percent of DM for the fertilized Abruzi rye. The analysis of variance (Appendix Table 3) shows that nitrogen effect, variety effect and the nitrogen x variety interaction are all highly significant (error b was used to test N effect--see footnote 1).

The nitrogen x variety table of ranked ADF means (Table 11) indicates that within the zero nitrogen treatment the oats had a significantly lower ADF content and thus a better digestibility than Stephens wheat, Adair and Casbon barley, the Triticales and both ryes. Abruzi rye had the highest ADF content. When nitrogen was applied at a rate of 133 kgs of N/ha Stephens wheat contained significantly less ADF than Casbon barley, the oats, the Triticales and the ryes. No significant different was recorded between Yamhill wheat, the barleys, the oats and the Triticales. Here, also, Abruzi rye had the highest ADF content.

B. Effect of Nitrogen on ADF

As shown in Table 12 the application of nitrogen fertilizer significantly increased the ADF content of all the cereal varieties except that of Abruzi rye and Sel N-91 Triticale. The largest ADF increases were recorded on Grey Winter oats with 60 percent, followed by Amity and Cayuse oats each increasing by respectively 59 and 45 percent.

Table 11. Mean ADF content in percent of DM of 13 cereal varieties at two nitrogen fertilizer levels

Variety	Zero nitrogen	Variety	133 kgs N/ha	Average
Grey Winter oats	23.65	Stephens wheat	34.3	32.6
Amity oats	23.88	FB 73130 barley	36.93	33.4
Cayuse oats	26.53	Yamhill wheat	37.6	33.2
Yamhill, wheat	28.78	Adair barley	37.85	36.4
FB 73130 barley	29.93	Grey Winter oats	37.98	30.8
Stephens wheat	30.88	Amity oats	38.03	30.9
VT 75-229 Triticale	34.38	Cayuse oats	38.55	32.5
Adair barley	34.95	Sel N-91 Triticale	39.25	38.4
Casbon barley	35.05	VT 75-229 Triticale	39.93	37.2
S-72 Triticale	36.45	S-72 Triticale	40.00	38.2
Sel N-91 Triticale	37.55	Casbon barley	40.13	37.6
Kung rye	38.55	Kung rye	42.75	40.7
Abruzi rye	46.10	Abruzi rye	46.78	46.4

$L.S.D._{.01} = 3.63$

Varieties joined by the same line are not significantly different.

Table 12. Difference due to the effect of nitrogen on the mean ADF content in percent of DM of 13 cereal varieties

Varieties	No nitrogen	133 kgs N/ha	Difference
Yamhill wheat	28.78	37.60	8.83**
Stephens wheat	30.88	34.30	3.43*
Cayuse oats	26.53	38.55	12.03**
Grey Winter oats	23.65	37.98	14.336**
Amity oats	23.88	38.03	14.15**
Casbon barley	35.05	40.13	5.08**
Adair barley	34.98	37.85	2.88*
FB 73130 barley	29.93	36.93	7.00**
Kung rye	38.55	42.75	4.20**
Abruzi rye (NC selection)	46.10	46.78	0.65
Sel N-91 Triticale	37.55	39.25	1.70
VT 75-229 Triticale	34.38	39.93	5.55**
S-72 Triticale	36.45	40.00	3.55*

$L.S.D._{.01} = 3.63$

* significant at the 5 percent level

**significant at the 1 percent level

Table 13. Mean adjusted (for yield) ADF content in percent of DM of 13 cereal varieties at two nitrogen fertilizer levels

Variety	N = Zero	Variety	N = 133 kgs/ha
Amity oats	26.61	Stephens wheat	31.15
Cayuse oats	28.26	Cayuse oats	34.05
Grey Winter oats	28.36	Yamhill wheat	34.42
Yamhill wheat	33.50	Adair barley	34.57
Stephens wheat	34.64	Amity oats	34.58
FB 73130 barley	35.33	Sel N-91 Triticale	34.79
VT 75-229 Triticale	36.61	VT 75-229 Triticale	35.13
Adair barley	37.55	Grey Winter oats	35.14
S-72 Triticale	39.00	FB-73130 barley	36.06
Casbon barley	39.56	S-72 Triticale	36.82
Sel N-91 Triticale	39.87	Casbon barley	39.88
Kung rye	41.90	Kung rye	40.78
Abruzi (NS Sel) rye	46.78	Abruzi (NC sel) rye	40.94

$L.S.D._{.01} = 3.84$

Varieties joined by the same line are not significantly different.

C. Adjusted ADF Content

Further regression analysis (Appendix Table 3) on ADF and yield revealed a strong linear relationship between yield and ADF content. Furthermore the analysis of variance on ADF when adjusted for yield showed that, on the average, nitrogen had no significant effect on ADF content. This signifies that practically all of the variation in ADF content of the cereal varieties can be explained by variation in yield, thus indicating that nitrogen affected ADF only indirectly by affecting yield. The same analysis (Appendix Table 3) showed that variety effect on ADF content and the variety x nitrogen interaction were both still significant after adjusting ADF to yield.

As shown in Table 13 within the zero nitrogen treatment, the oats had a significantly lower adjusted ADF content than all the other varieties. The wheat, barleys and Triticales had an intermediate ADF content whereas the ryes had the high ADF content, particularly the Abruzi line which was significantly higher than all the others. At the 133 kgs of N/ha level, Stephens wheat had a substantially low ADF content followed by Yamhill wheat, the oats, the Triticales and the FB 73130 and Adair barley with no significant differences between them. Casbon barley, Kung and Abruzi ryes had significantly higher ADF value than all the other varieties except FB-13130 and Casbon barleys with which differences were not significant.

4. Neutral Detergent Fiber

A. Neutral Detergent Fiber (NDF) Content

NDF content of the 13 cereal varieties ranged from a low of 39.3 percent of the dry matter (DM) for the no nitrogen Grey Winter oats to a high of 69.5 percent of DM for the nitrogen fertilized Abruzi rye. The analysis of variance (Appendix Table 4) showed that nitrogen had a significant effect on increasing NDF content when averaged over all varieties. It also showed a highly significant variety effect and nitrogen x variety interaction.

The study of the nitrogen x variety table of ranked NDF means (Table 14) showed that at the zero nitrogen level the oats varieties were significantly lower in NDF than the barley, Triticale and rye varieties but not significantly different from the wheats. The barley and Triticale varieties were all significantly lower in NDF than Abruzi rye which had the highest NDF content and thus would be the least appealing to animals. When nitrogen fertilizer was applied, Stephens wheat had the lowest NDF content but was not significantly lower than the oats, Yamhill wheat or the FB 73130 and Adair barleys. Cayuse and Grey Winter oats, which ranked respectively third and fourth lowest in NDF, were significantly lower than the ryes but not significantly lower than Yamhill wheat, the barleys and triticales.

B. Effect of Nitrogen on NDF

Table 15 shows that NDF content differences between fertilized and non-fertilized varieties were all significant except with the Abruzi rye. Nitrogen fertilizer significantly increased NDF content in all varieties

Table 14. Mean NDF content in percent of DM of 13 cereal varieties at two nitrogen levels

Variety	Zero nitrogen	Variety	133 kgs N/ha	Average
Grey Winter oats	39.30	Stephens wheat	58.58	54.8
Amity oats	41.88	Amity oats	59.50	50.7
Cayuse oats	46.18	Cayuse oats	61.20	53.7
Yamhill wheat	48.65	Grey Winter oats	61.23	50.3
Stephens wheat	51.00	Yamhill wheat	61.63	55.1
FB 73130 barley	53.93	FB 73130 barley	63.30	58.6
VT 75-229 Triticale	55.48	Adair barley	63.63	60.9
Casbon barley	57.43	Sel N-91 Triticale	63.70	61.1
S-72 Triticale	57.75	Casbon barley	64.23	60.8
Adair barley	58.30	VT 75-229 Triticale	64.63	60.1
Sel N-91 Triticale	58.50	S-72 Triticale	65.88	61.8
Kung rye	61.50	Kung rye	67.05	64.3
Abruzi rye	69.5	Abruzi rye	69.13	69.4

$L.S.D._{.01} = 5.07$

Varieties joined by the same line are not significantly different.

Table 15. Difference due to the effect of nitrogen on the mean NDF content in percent of DM of 13 cereal varieties

Variety	No nitrogen	133 kgs/N/ha	Difference
Yamhill wheat	48.65	61.63	12.98**
Stephens wheat	51.00	58.58	7.58**
Cayuse oats	46.18	61.20	15.02**
Grey Winter oats	39.30	61.23	21.93**
Amity oats	41.88	59.50	17.62**
Casbon barley	57.43	64.23	6.8**
Adair barley	58.30	63.63	5.33**
Fb 73130 barley	53.93	63.30	9.37**
Kung rye	61.50	67.05	5.55**
Abruzi rye (NC Sel)	69.50	69.13	-0.37 NS
Sel - N-91 Triticale	58.50	63.70	5.2**
VT 75-229 Triticale	55.48	64.63	9.15**
S-72 Triticale	57.75	65.88	8.13**

$L.S.D._{.01} = 5.07$

* significant at the 5 percent level

**significant at the 1 percent level

except Abruzi rye where a non-significant decrease in NDF was observed. The higher increases came about with Grey Winter oats whose NDF content increased by 55 percent, followed by Amity oats which increased by 42 percent, then Cayuse oats and Yamhill wheat which increased respectively by 32 and 26 percent.

C. Adjusted NDF Content

Further analysis on the NDF content and particularly its regression on yield (Appendix Table 4) revealed that a highly significant linear relationship existed between yield and NDF content. The covariance analysis (Appendix Table 4) showed that when NDF content was adjusted for yield its response to nitrogen application was no longer significant. This demonstrates that nitrogen does not directly affect NDF content and that most of the variation in NDF can be accounted for by variation in yield rather than nitrogen. The covariance analysis also showed that even after NDF content was adjusted for yield, variety effect and nitrogen x variety interaction were still highly significant.

Table 16 shows that at the zero nitrogen level the oats varieties had a significantly lower adjusted NDF content than any other variety. The wheats were second lowest in NDF followed by VT-75-229 and S-72 Triticales. All were significantly lower in NDF than Abruzi rye which had the highest NDF. When nitrogen fertilizer was applied Stephens wheat showed a non-significant low NDF content followed with similar values by the oats varieties, Yamhill wheat, Sel N-91 and VT 75-229 Triticale. Kung rye had the highest adjusted NDF content.

Table 16. Mean adjusted (for yield) NDF content in percent of DM of 13 cereal varieties at two nitrogen levels

Variety	N = Zero	Variety	N = 133 kgs N/ha
Amity oats	45.61	Stephens wheat	54.29
Grey Winter oats	45.73	Amity oats	54.81
Cayuse oats	48.53	Cayuse oats	55.07
Yamhill wheat	55.08	Yamhill wheat	57.30
Stephens wheat	56.12	Grey Winter Oats	57.36
VT 75-229 Triticale	58.52	Sel N-91 Triticale	57.63
S-72 Triticale	61.23	VT 75-229 Triticale	58.09
FB 73-130 barley	61.29	Adair barley	59.16
Sel N-91 Triticale	61.67	Abruzi (NC) rye	61.16
Adair barley	61.80	S-72 Triticale	61.54
Casbon barley	63.57	FB 73-130 barley	62.11
Kung rye	66.06	Casbon barley	63.83
Abruzi (NC Sel) rye	70.43	Kung rye	64.36

L.S.D.$_{.01}$ = 5.55

Varieties joined by the same line are not significantly different.

V. SUMMARY AND CONCLUSION

A study of the yield and nutritional quality of 13 cereal varieties for winter silage production was conducted during the 1978 and 1979 growing seasons at the Hyslop and Dairy Center field laboratories of Oregon State University. The yield, crude protein (CP) content, acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined and compared for all varieties at two nitrogen fertilizer levels, a 133 kgs of N/ha level and a zero N/ha control level. On the basis of the data collected during the experiment, the following results were obtained:

1. Yield of dry matter was significantly influenced by both variety and nitrogen fertilizer.
2. The highest average yield was given by Abruzi rye followed by Sel N-91 Triticale, VT 75-229 Triticale, S-72 Triticale, Kung rye, Yamhill and Stephens wheat.
3. Application of 133 kgs of N/ha increased the average yield by a significant 108 percent.
4. Crude protein (CP) content varied from 5.1 percent in the non-fertilized Abruzi rye to 11.03 percent in the fertilized Casbon barley.
5. The barley, wheat and Triticale varieties exhibited significantly higher CP contents than the oats or Abruzi rye at the 133 kgs of N/ha fertilizer level.
6. Nitrogen fertilizer significantly increased CP content in all varieties except in the FB 73130 barley variety.

7. CP content had a significant linear relationship with yield.
8. Nitrogen's increase of CP content was still significant even after adjusting CP for yield indicating that nitrogen has a direct effect on CP content of the cereal varieties.
9. Acid detergent fiber (ADF) content ranged from 23.65 percent of DM for the non-fertilized Grey Winter oats to a high of 46.78 percent for the fertilized Abruzi rye.
10. When nitrogen fertilizer was applied, Stephens wheat had the lowest value for ADF; Yamhill wheat, the barleys, the oats and the Triticales followed with no significant difference among them.
11. ADF content had a significant linear relationship with yield.
12. The application of nitrogen fertilizer significantly increased ADF content in the cereal varieties, but when ADF was adjusted for yield the increase in ADF due to nitrogen was no longer significant indicating that nitrogen affects ADF only through yield.
13. Neutral detergent fiber (NDF) ranged from 39.3 percent of the DM for the non-fertilized Grey Winter oats to a high of 69.5 percent of DM for the fertilizer Abruzi rye.
14. Stephens wheat had a significantly lower NDF than the ryes and Triticales. The triticales, however, were not significantly higher in NDF than Yamhill wheat and the barleys.
15. NDF is linearly related to yield. Nitrogen fertilizer significantly increased the NDF content of the cereal varieties. However, when NDF was adjusted for yield, the effect of nitrogen was no longer significant, indicating that NDF like ADF was affected by nitrogen only through yield and not directly.

In conclusion and based upon the data obtained in this experiment, the application of nitrogen fertilizer is a necessity since its increase of the yields and crude protein contents of nearly all the cereal varieties is highly economical. With respect to the varietal choice, Cayuse oats likely has no place in a double cropping system as a winter crop since, as mentioned before, it cannot withstand below-freezing temperatures. Grey Winter and Amity oats and all three barley varieties, in spite of their relatively high quality for silage should be discarded because of their low yields. The ryes and particularly the Abruzi line, have shown considerably high contents of fibers and have been known for a long time for their unpalatability (Thatcher, 1934).

As shown in Table 17, it seems that Stephens and Yamhill wheats and the Triticales constitute the varieties of choice to be used for the high level production of a good quality silage in a double cropping system with corn.

Table 17. Yield, CP, ADF and NDF contents of the best, fertilized cereal varieties to be recommended for use in a double cropping system with corn

		Percent of DM		
Variety	Yield in kg/ha	CP	ADF	NDF
Sel N-91 Triticale	7948	10.23	39.25	63.70
VT 75-229 Triticale	7727	10.00	39.93	64.63
S-72 Triticale	6785	10.68	40.00	65.88
Yamhill wheat	64.27	10.23	37.60	61.63
Stephens wheat	63.28	11.00	34.30	58.58

REFERENCES CITED

Bishnoi, U. R., P. Chitapong, J. Hughes, and J. Nishimuta. 1978. Quantity and quality of triticale and other small grain silages. Agron. J. Vol. 70. May-June, 1978.

Brown, A. R., and A. Almodares. 1976. Quantity and quality of triticale forage compared to other small grains. Agron. J. Vol. 68. March-April, 1976.

Burgess, P. L., Nicholson, J. W. G. and E. A. Grant. 1973. Yield and nutritive value of corn, barley, wheat, and forage oats for lactating dairy cows. Can. J. Anim. Sci. 53: 245-250.

Calhoun, Wheeler. A summary of climate and weather for Corvallis, Oregon. 1889 through 1960. Corvallis, 1961. 12 p. (Oregon Agricultural Experiment Station. Miscellaneous paper No. 105).

Camper, H. M., C. F. Genter, and K. E. Loope. 1972. Double cropping following winter barley harvest in eastern Virginia. Agron. J. 64: 1-3.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15: 383-395.

Dalrymple, Dana G. 1971. Survey of multiple cropping in less developed nations. Foreign economic development service. U.S.D.A. cooperation with the U.S. Agency of International Development.

Davidson, J. and J. A. Leclerc. 1918. The effect of sodium nitrate applied at different stages of growth on yield, composition, and quality of wheat-2. Jour. Amer. Soc. Agron. 10: 193-198.

Fisher, L. J. and D. B. Fowler. 1975. Predicted forage value of whole plant cereals. Can. J. Plant Sci. 55: 975-986.

Goering, H. K. and P. J. van Soest. 1970. Forage fiber analysis. U.S.D.A. Agr. Handbook 379.

Hansen, L. 1891. Calif. Exp. Sta. Report 1891-92. pp. 186-189.

Hendry, George W. 1925. I. cereal hay production in California. Calif. Agr. Expt. Sta. Bull. 394.

Jackman, E. R. and M. Oveson. 1955. Grain hay and pasture in the Columbia Basin. Oregon State College Fed. Coop. Ext. Serv. Ext. Circular 590.

Lawes, O. A. and D. I. H. Jones. 1971. Yield, nutritive value and eusiling characteristics of whole-crop spring cereals. J. Agric. Sci. (Lamb.) 76: 479-485.

Luh, C. L. "Report on vegetable production survey in southeast Asian countries" Seminar on Food Problem in Asia and the Pacific, Honolulu. May, 1970. pp. 12-13.

Morrisson, F. B. 1956. Feeds and feeding. 22nd edition. Morrison, Ithaca, NY.

Murdok, L. W., K. L. Wells. 1978. Yields, nutrient removals, and nutrient concentrations of double-cropped corn and small grain silage. Agron. J. Vol. 70: 573-576.

OR Soils-1. 12/72 - 3/7/73. Soil interpretations for Oregon. U.S.D.A. Soil Conservation Service.

OR Soils - 1 - 12/72. 2/1973. Soil interpretations for Oregon. U.S.D.A. Soil conservation service.

Raymond, W. F. and A. J. Heard. 1968. The eusilage of whole-crop cereals. Home-grown cereals authority, Journal Cres. Lond. No. 4, pp. 7-11.

Rohweder, D. A., F. F. Barnes, and Neal Jorgensen. 1974. Marketing Hay on the Basis of Analysis. Progress Report from the Forage Analysis Subcommittee of the Hay Marketing Task Force Organized by the American Forage and Grassland Council.

Schneider, B. H. 1947. Feeds of the world. p. XXV + 229 W. Va. Agric. Expt. Sta.

Thatcher, L. E. 1934. Cereal Hays for Ohio. Ohio Agric. Expt. Sta. Bull. 543.

Tingle, J. N. and Dawley, W. K. 1974. Yield and nutritive value of whole plant cereals at a silage stand. Can. J. Plant Sci. 54: 621-624.

Van Soest, P. J. 1964. Symposium on nutrition and forage and pastures; new chemical procedures for evaluating forages. J. Animal Sci. 23, 838-845.

Van Soest, P. J. 1967. Development of a comprehensive system of feed analysis and its application to forages. J. Animal Sci. 26. 119-128.

Van Soest, P. J. 1971. Newer methods of forage evaluation. N. Y. Food and Life Sci. Quart. 4 (Oct-Dec.): 4-6.

Van Soest, P. J. 1976. Composition and nutritive value of forages. Forages 3rd edition by M. E. Heath, Dis. Metcalfe. R. F. Barnes 10: 53-63.

Van Soest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds IV. The determination of plant cell-wall constituents. J. Ass. Office Agr. Chem. 50, 50-55.

Woll, F. W. 1925. II. Feeding trials with cereal hays. Calif. Agr. Exp. Sta. Bull. 394.

APPENDIX

Table A-1. The analysis of variance for yields of dry matter

Source of variation	df	Mean square	F
Year	1	579701	
Loc	1	75337900	
Year x Loc	1	45462500	
Block	1	4997460	
Year x Block			
Loc. x Block			
Year x Loc. x Block	3	2909920	
Nitrogen	1	941056000	68.79**
Year x nitrogen	1	95922900	7.01
Loc. x nitrogen	1	43901400	3.21
Year x Loc. x nitro	1	34809300	2.54
Block x nitro			
Year x Block x nitro			
Loc. x Block x nitro			
Year x Loc. x Block x nitro	4	13679900	
Variety	11	26527500	24.86**
Year x Variety	11	4635640	4.34**
Location x Variety	11	2497830	2.34*
Year x Loc. x Var.	11	1338080	1.25
Nitrogen x Var.	11	1126920	1.06
Year x nitrogen x Var.	11	8261680	.77
Loc. x nitrogen x Var.	11	1636840	1.53
Year x Loc. x nitro x Var.	11	1519820	1.42
Error	88	1067230	
Total	181		

* Significant at the 5 percent level
**Significant at the 1 percent level

Table A-2. Covariance analysis of CP on yield

Source of Variation	ANOVA dF	ANOVA Mean Square CP	ANOVA Mean Square Yield	ANCOVA-CP on Yield dF	ANCOVA-CP on Yield Ms CP Adjusted	F CP	F Yield	F CP Adjusted
Blocks	3	.3	551798	3	.19			
Nitrogen	1	293.8	852859000	1	45.32	149.1**	226.5**	48.8**
Bl x N = Ea	3	1.9	3765800		.79			
Variety	12	7.3	13316000	12	14.94	10.4**	10.5**	16.35**
Nx Vr	12	2.2	1488670	12	2.30	3.1**	1.2_{NS}	2.48*
Error b	72	.6	1260190	71	.92			
Regression on yield				1	144.06			155.4**
TOTAL	103			103				

*Significant at the 5 percent level
**Significant at the 1 percent level

Table A-3. Covariance analysis of ADF on yield

Source of Variation	ANOVA dF	ANOVA Mean Square ADF	ANOVA Mean Square Yield	ANCOVA ADF on Yield df	ANCOVA ADF on Yield Ms ADF Adjusted	F ADF	F Yield	F ADF Adjusted
Blocks	3	13.6	551798	3	9.9			
Nitrogen	1	1069.4	852859000	1	0.1	284.4**	226.5**	.02
Bl x N = Ea	3	1.6	3765800		5.4			
Variety	12	157.2	13316000	12	130.7	41.8**	10.5**	31.1**
N x Vr	12	42.1	1488670	12	39.1	11.2**	1.2	9.3**
Error b	72	3.8	1260190	71	4.2			
Regression on Yield				1	1393.3			331.7**
TOTAL	103			103				

* Significant at the 5 percent level
**Significant at the 1 percent level

Table A-4. Covariance analysis of NDF on yield

Source of variation	ANOVA df	ANOVA Mean Square NDF	ANOVA Mean Square Yield	ANCOVA NDF on Yield df	ANCOVA Ms NDF Adjusted	F NDF	F Yield	F NDF Adjusted
Blocks	3	18.2	551798	3	11.8			
Nitrogen	1	2383.7	852859000	1	22.0	325.6**	226.5**	174
Bl x N = Ea	3	5.3	3765800		12.7			
Variety	12	240.7	13316000	12	221.9	32.9**	10.5**	25.2**
N x Vr	12	70.2	1488670	12	61.7	9.6**	1.2	7.0**
Error b	72	7.3	1260190	71	8.8			
Regression on Yield				1	2589.8			294.6**
TOTAL	103			103				

* Significant at the 5 percent level
**Significant at the 1 percent level